Coastal and Inland Water Environmental Monitoring in Japan Using Hyperion Data

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1. Objective

The objective of this study is to evaluate Hyperion's capability to map and monitor coastal and inland water environments in Japan. Especially, we focused on shallow fringing coral reefs and brackish lakes.

2. Study Area and Hyperion Data

Our original study areas were Lake Shinji in Shimane Prefecture and two coral reefs in Ishigaki Island, Okinawa Prefecture. Unfortunately, the only cloud-free Hyperion data we have received so far is that of Shiraho coral reef in Ishigaki(see below and Figure 1). Thus we concentrated on this Shiraho data.

Observation Date	October 2, 2001.
Observation Time	11:00 am (Japanese Standard Time)
Study Area Coordinate	N24° 27', E124° 14' (Center)
Tide Level at Ishigaki Port	85 cm (High and low tide level of this day were 178 cm and 47 cm, respectively.
Product	Level -1R

3. Hyperion Data Processing

3.1 Data Processing Procedures

The data processing procedures in this study are summarized below.

(1) Atmospheric correction and conversion to surface reflectance using ACORN 4 software.

(2) Calculation of "Hyperspectral Coral Reef Indices"

(3) Generation of simulated ETM+ data from Hyperion surface reflectance data.

(4) Calculation of "Lyzenga-type Bottom Indices"

(5) Georeferencing of Hyperion data using DGPS data

(6) Comparison between calculated indices and sea floor cover data from photo interpretation of aerial photographs in late 90s.

(7) Comparison between calculated indices and sea floor cover data acquired during the

2002 field survey.

3.2 Spectral Signatures of Benthic Habitats and Hyperspectral Coral Reef Indices

According to Hyperion data evaluation prior to detailed analysis, it was indicated that Hyperion could not detect light longer than 700 nm reflected at sea floor deeper than approximately 5 m. Note that this depth itself is a function of sea water quality parameters and solar elevation and may change scene to scene. Due to this depth limitation, we focused on areas shallower than 5 m in Shiraho Reef. Typical Hyperion reflectance spectra of Shiraho Coral Reef are shown in Figure 2.

Several researchers have reported diagnostic spectral signatures of corals, seagrass, and algae especially in the 500-600 nm spectral region [1), 2), 3)]. Unfortunately, such signatures were difficult to extract from our Hyperion data partly because of low signal to noise ratio of Hyperion and smaller-than-pixel patches of corals and others in the shallow part of Shiraho. Thus, in this study, we used spectral signatures around 700 nm for benthic habitat classification. Although this spectral region is more sensitive to sea depth than the 500-600 nm region, diagnostic signals from shallow benthic communities were much stronger than other spectral regions. Based on knowledge from previous field and airborne spectral measurements in coral reefs, we are proposing the following "Hyperspectral Coral Reef Indices" as shown in Figure 3.

1) Chlorophyll-a Absorption Depth(**CAD**)

$$\mathbf{CAD} = 1 - 2\, R_{681}/(R_{650}+R_{711})$$

2) Curvature at 711 nm(**CVT**)

$$\mathbf{CVT} = 2\, R_{711}/(R_{680}+R_{732})-1$$

3) Pseudo Peak Height(**PPH**)

$$\mathbf{PPH} = 2\, R_{701}/(R_{690} + R_{711})-1$$

3.3 **Lyzenga-type Bottom Index**

Lyzenga-type Bottom Indices [4], which is independent from sea water depth and functions of sea floor spectral reflectance only, can be calculated from any combinations of Hyperion bands using the following formula.

$$BI_{i,j} = \ln (\rho_i / \rho_j^{\,k'}) \qquad \text{where } k' = k_i/k_j$$

k_i and k_j are attenuation coefficients of sea water at band i and j, respectively.

We applied the above formula to ETM+ band data simulated from Hyperion data. BI_{12} was calculated from simulated ETM+ Band 1 and Band 2, and BI_{23} is calculated from Band 2 and Band 3. Both BIs can be related to the amount of sand cover in a pixel [5]. Non-sand sea floor cover include corals, seagrass, algae, and reef rock.

4. Results

4.1 Simulated ETM+ Data

One of major problems of coral reef remote sensing using Landsat-type satellite imagery is that although "sand" pixels can be easily separated from pixels with benthic communities such as corals, it is often difficult to discriminate coral, algae, and seagrass. This is mainly because their spectral signatures, convolved with broad spectral response functions of Landsat-type sensors, are almost similar. This fact is also shown in Figure 4 (upper center). In this figure, pixels with benthic habitats, red soil, and reef rocks, are plotted very closely. Thus it is very difficult to separate them using Landsat bands. Figure 4 (upper right) shows the relationship between BIs and sea floor cover type. Although the previous study [5] suggested that BIs are useful for separation of sand and others, it is still difficult to classify corals, algae, seagrass, and so on.

4.2 Hyperspectral Coral Reef Indices from Hyperion Data

Figure 4 (lower center and right) show the relationship between three Hyperspectral Coral Reef Indices and training areas determined from photo interpretation of aerial photographs in late 90s. It is clearly shown that in both figures, corals are plotted at different regions in the diagrams from other sea floor covers. Thus by setting threshold values for three indices, "coral" pixels can be separated from other pixels such as sand, seagrass, and algae. If

Lyzenga-type Bottom Indices from simulated ETM+ data are used for classification together, "sand", "coral", and "other" pixels can be discriminated.

Figure 5 show the relationship between three Hyperspectral Coral Reef Indices and sea floor cover type from the field survey in December 2002. As the main purpose of this field survey was the evaluation of Ikonos capability to map Japanese coral reefs, sea floor cover types were described in 1-10 m scale which is smaller than the pixel size of Hyperion. This scale difference may cause additional discrepancy between Hyperion indices and field data. Figure 5 (left) is for pure pixels in which more than 80% of the area was covered with a single type according to the field survey. As expected from Figure 4, all "live coral" pixels have higher CAD values than any "seagrass" pixels. Thus CAD can be used for separation of live corals and seagrass. Instead, it is difficult to separate "reef rock" pixels from others. This is partly because "reef rock" pixels often contain algae and corals which live on the surface of these rocks. There were no pure "algae" pixels, and the separation of coral and algae cannot be discussed here.

Figure 5 (right) is for all pixels. Although the relationship shown in Figure 5(left) was obscured, all "live coral" pixels still have higher CAD values than "seagrass" pixels.

5. Summary

Hyperion's capability to map shallow fringing coral reefs was evaluated in this study. Comparisons between indices from Hyperion data and field survey results suggested that sea floor cover classification with three categories, sand, coral, and others such as algae and seagrass can be possible using the spectral signatures around 700 nm. Such classification is often difficult for Landsat-type broadband sensors. Separation of algae and seagrass may require higher signal-to-noise ratio in the 500-600 nm than Hyperion.

References

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2) H. Yamano, M. Tamura, Y. Kunii, and M. Hidaka, Hyperspectral remote sensing and

radiative transfer simulation as a tool for monitoring coral reef health, Marine Technology Society Journal, 36, 1, pp. 4-13, 2002.

3) H. Yamano, T. Matsunaga, and T. Ikema, Airborne hyperspectral measurement of coral reefs around Akajima, Okinawa, Japan, Proceedings of 34th Annual Conference of Remote Sensing Society of Japan, pp. 35-38, 2003.
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Publication List

1) T. Matsunaga, A. Iwasaki, S. Tsuchida, and H. Yamano, A study of data processing methods for hyperspectral data in coral reef using EO-1 Hyperion data of east Ishigaki Island, Proceedings of 34th Annual Conference of Remote Sensing Society of Japan, pp. 259-260, 2003.
2) T. Matsunaga, S. Tsuchida, and A. Iwasaki, Satellite hyperspectral observation of north Ishigaki Island by Earth Observing 1 Hyperion, Proceedings of 31st Annual Conference of Remote Sensing Society of Japan, pp. 47-48, 2001.

Figures

Figure 1. Hyperion surface reflectance image of Shiraho Coral Reef in Ishigaki Island, Japan.

Blue = 487.9 nm, Green = 559.1 nm, Red = 660.9 nm.

2002 survey points are shown as small orange dots.

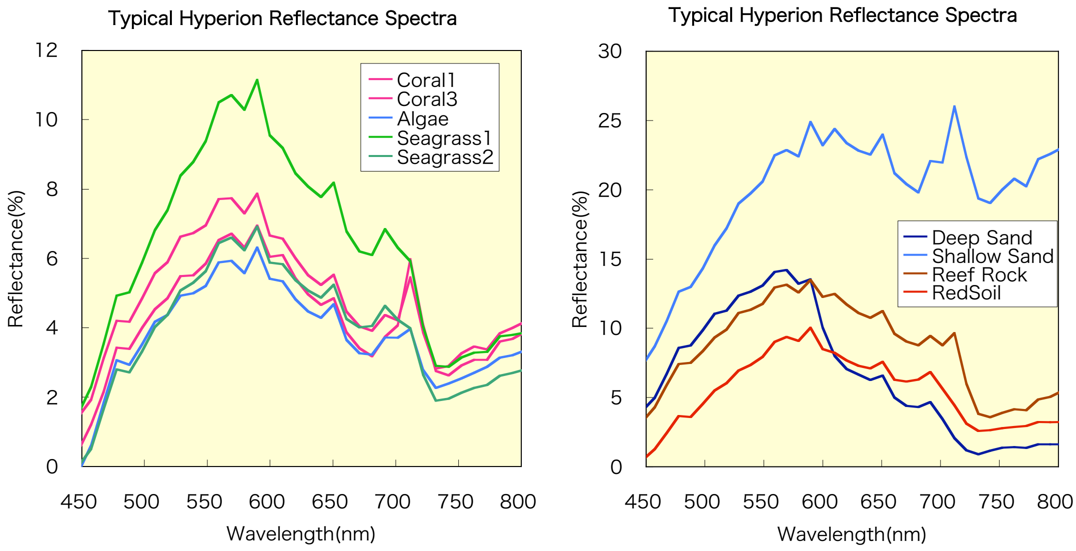

Figure 2. Typical Hyperion reflectance spectra of Shiraho Coral Reef.

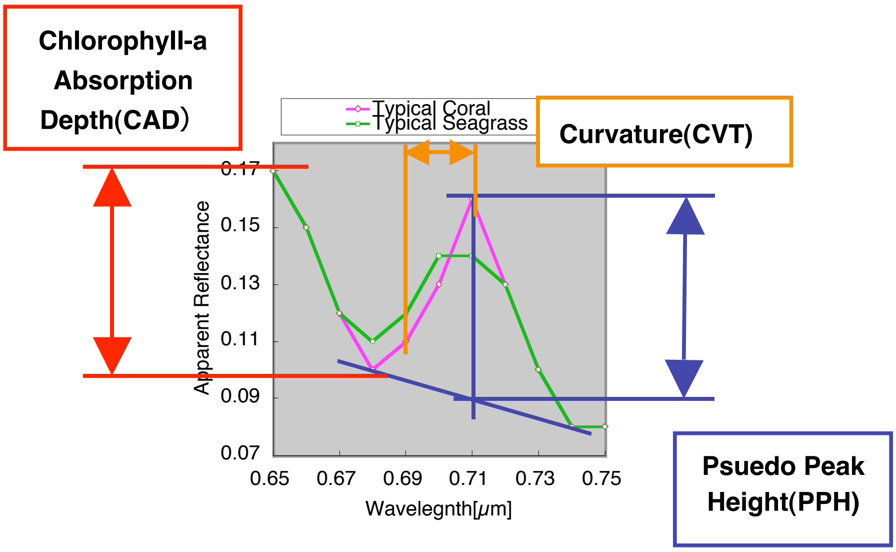

Figure 3. Hyperspectral Coral Indices.

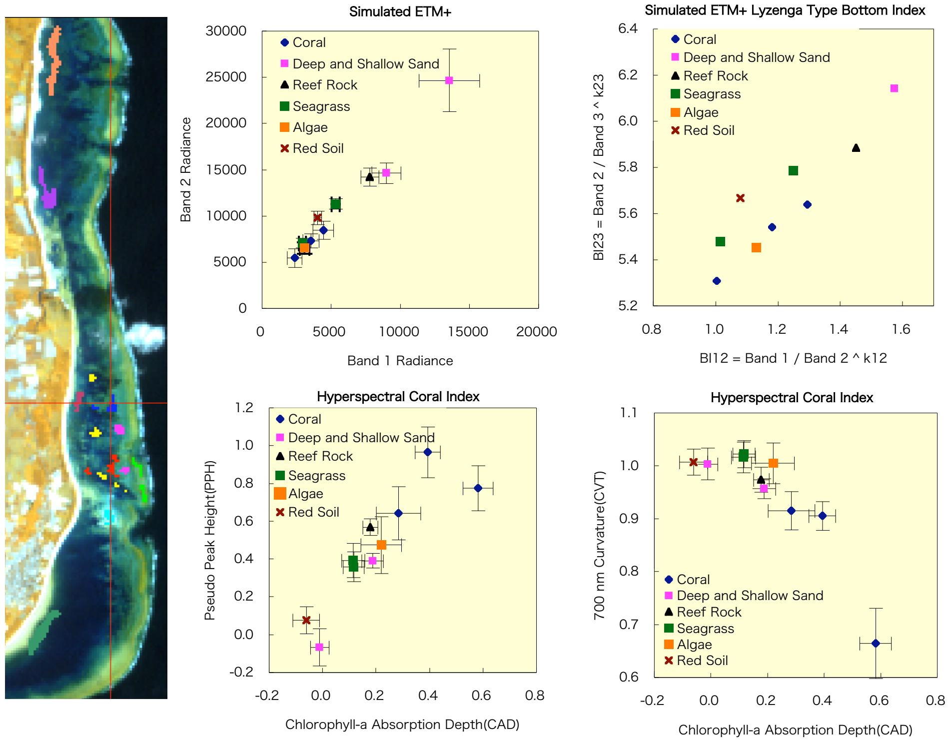

Figure 4. Training area characteristics:

(left) Locations of training areas:

light and dark brown : seagrass, green : algae,

yellow : deep and shallow sand, pink : reef rock, orange : coral

(upper center) Simulated ETM+ Band 1 and Band 2 data,

(upper right) Lyzenga-type Bottom Indices from simulated ETM+ data,

(lower center) CAD and PPH, and

(lower right) CAD and CVT

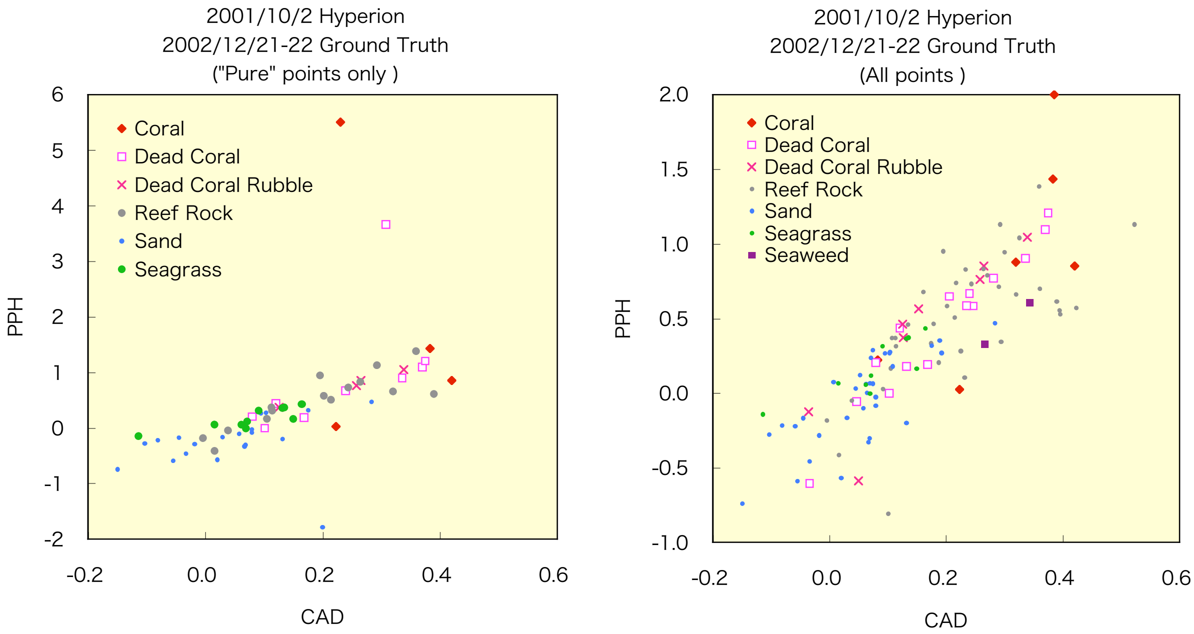

Figure 5. Comparison between "Hyperspectral Coral Reef Indices" and 2002 field survey results.